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ABSTRACT

Using reaction time, the interaction between stimulus sentences requiring varying degrees of inferential activity and tasks requiring different levels of cognitive processing is investigated. Effects of thematic and nonthematic contexts are also examined. Results suggest that analyses of processing time may provide useful insights into the comprehension process. (Author)

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Identification of Component Processes in Sentence Comprehension[1]

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Abstract

Using reaction time, the interaction between stimulus sentences requiring varying degrees of inferential activity and tasks requiring different levels of cognitive processing is investigated. Effects of thematic and non-thematic contexts are also examined. Results suggest that analyses of processing time may provide useful insights into the comprehension process.

CS 201 339

I'll report today on some preliminary data we've obtained on the problem of identifying component processes in comprehension. In this work we use a RT analysis to attempt to characterize some very general types of cognitive processes in adult's comprehension of ordinary English sentences. We will be concerned with identifying general processes rather than specific encoding transformations or strategies, and we deal with materials and tasks that are not too far removed from those that a subject encounters outside the laboratory. Before I present the data, however, a few comments about the methodological strategy are in order.

An approach often taken in information-processing research is to assume that the phenomenon under study can be broken down into successive stages with independent durations (c.f., Haber, 1969; Sternberg, 1968; Theios, 1972). In formulating general models of language comprehension, however, it seems likely that the assumption of strictly independent successive stages will prove too restrictive.[2] Studies of reading, for example, generally assign an important role to feedback or "outflow" from higher to lower level processes (c.f., Brewer, 1972; Brown, 1970; Hochberg & Brooks, 1970; Mattingly, 1972). Recent work in computer simulation of natural language understanding also emphasizes interaction or "cross talk" between component processes (c.f., Schank, 1972; Winograd, 1972). In this work component processes may call one another as subroutines, hence one component will not necessarily be completed before another begins. These ideas are consistent with psycholinguistic research which shows that semantic and pragmatic, as well as syntactic, factors can play an important role in comprehension (c.f., Bever, 1970; Foss, 1971).

The method of the present study is designed to isolate component processes in comprehension without necessitating the assumptions that the components are either strictly serial or independent. This approach is closely related to that used by Posner and his colleagues in their work on classification (c.f., Posner, Lewis, & Conrad, 1972; Posner & Mitchell, 1967). The method involves measuring

reaction time (RT) for sentence processing in each of several tasks. Tasks are chosen so that they involve many, but not all, of the same component processes. There are two main advantages to using different tasks, and these advantages depend on the assumption that tasks differ in the kind of processes they require rather than simply in amount of processing. First, between-task differences in effects of other independent variables allow one to make statements about the component processes involved in each task (e.g., Dooling, 1972; and Mistler-Lachman, 1972 have used this method in language comprehension research). This information is important because it can provide insights into how the tangle of interacting processes presumably involved in comprehension can be functionally separated. Obviously, the results of a single manipulation will not be conclusive. A variable may be affecting some process other than that which the experimenter has in mind, or his assumptions about the component processes involved in a particular task could be wrong. In order for the results to be conclusive it is necessary to find internally consistent results from a number of manipulations and studies.

The second advantage to using different tasks is that one may be able to study certain components in isolation from other interacting processes by concentrating on effects within a particular task. The general strategy for identifying cognitive operations, of course, is to find clusters of variables which converge in some predictable manner (c.f., Garner, Hake & Eriksen, 1956). However, if component processes are not independent, it may be difficult or impossible to isolate such clusters, since variables which affect one component will also have indirect effects on others. By studying interactions in simpler tasks one may be able to eliminate certain component processes, and hence some of the indirect effects. A by-product of this method is that one obtains information about which processes do or do not interact, i.e., information about the functional relationships between components.

The methodological strategy, then, is to make some educated guesses about the general types of processes which might be involved in comprehension. These guesses are then tested by selecting tasks and other independent variables which should interact in certain predictable ways if one's guesses are correct.

In our initial study the selection of tasks and variables was motivated by a conceptualization of sentence comprehension as involving the following three general types of processes: (a) retrieval of information about words (or lexical items) from semantic memory, (b) synthesis of word-meaning information, contextual constraints, and syntactic constraints to form a semantic representation for larger-than-word-size units (e.g., sentences or clauses), (c) interpretation, integration, and evaluation of the implications of the encoded sentence in terms of S's nonlinguistic or "world" knowledge.

We chose three tasks such that the first would involve only the first component (or actually a part thereof), the second would require both the first and second components, and the third, all three components.

The lowest level task involved scanning sentences for spelling errors or "non-words". This task is called the SP or spelling condition. The S viewed both acceptable and unacceptable sentences (see page 1 of the handout) and responded yes or no by pressing one of two buttons. The most processing this task should require (though it may of course involve more) is a lexical search process, in which S "looks-up" a letter string to determine whether it is a word. Lexical look-up should be involved to the extent that S cannot detect non-word letter strings on some other basis, such as lack of pronounceability or low letter-transition probabilities. A second task involved judgments of meaningfulness or semantic acceptability. This I'll refer to as the MN or meaning task. This task requires, at a minimum, that S determine whether the string of words presented has a "meaning" or a reasonable interpretation. Of course, determining whether a string of words has an interpretation may not involve spelling processes.

what the interpretation is. Hence the MN task may require less than complete comprehension. In particular, results obtained by Dooling (1972) and Mistler-Lachman (1972) suggest that the MN task may not involve integration or interpretation of the sentence with context or prior nonlinguistic knowledge. The third task was designed to involve full interpretation or integration of the sentence. Subjects were asked to carefully read the sentence and press a response button as soon as they felt prepared: (a) to paraphrase the sentence, or (b) to generate a continuation sentence on the same theme. In order to keep S honest, he was required to write down a paraphrase or continuation sentence immediately after responding on a randomly selected one-third of the trials. The S was given 20 sec. in which to do so.

The other independent variables were semantically different types of sentences and thematic as opposed to non-thematic contexts. Three types of sentences were chosen which seemed likely to involve different amounts of processing on various levels: (a) redundant (RDT) sentences, (b) informative (INF) sentences, and (c) referentially vague or ambiguous (AMB) sentences (see page 1 of the handout for examples).

Results reported by Steinberg (1970 a, b) and Kintsch, Crothers, and Berman (1971) suggest that the redundant-informative distinction bears some correspondence to psychological processes. The work of Collins and Quillian (1972) suggests that Ss may be able to comprehend redundant sentences by drawing inferences based on closely related concepts stored in semantic memory. In comprehending informative sentences, however, S must relate concepts that span a larger semantic distance, and deal with more complex relationships. The additional processing required for informative sentences does not seem likely to affect the lexical look-up process required in the SP task, but may affect the synthesis process required in the MN task. We therefore predicted that informative sentences would show a larger increase in RT from the SP to the MN

task than would redundant sentences.

Results from a number of studies (c.f. Bransford & Johnson, 1972; Doll & Lapinski, 1972) suggest that ambiguous sentences are more likely to require integration and interpretation in terms of prior knowledge than are redundant and informative sentences. Such sentences should therefore show a greater increase from MN to PR or from SP to PR than redundant and informative sentences.

There were three context conditions: Neutral (N) contexts were simply a string of asterisks. Duplicative (D) contexts consisted of one or two words which were synonymous or highly assocated with a word in the sentence, but which were not closely related to the meaning of the sentence as a whole. And third, Referential (R) contexts were constructed so as to suggest a theme or referential setting for the sentence.

Duplicative contexts should affect primarily the first component discussed above, i.e., retrieval of information about words or lexical items. This component is presumably involved in all three tasks to about the same extent; hence D contexts should be equally effective in all tasks. Referential contexts should have an effect in the third component (interpretation) as well as the others; hence its effect should be greater in PR than in the other tasks, particularly for ambiguous sentences.

Method

Design. Twelve Ss were haphazardly assigned to each task condition. Each S experienced all three types of sentences and the three context conditions.

Materials. There was a total of 144 acceptable sentences, 48 of each type, redundant, informative and ambiguous. Number of words length and average word frequency were matched between sentence types, and sentences were counterbalanced over context conditions.

Unacceptable sentences were generated by starting from base sentences of each type and changing either letter order within one of the words (for the SP

task) or word order and endings (for the MN task). An effort was made to keep the altered letter strings as pronounceable as possible and the anomalous sentences as grammatical as possible. In making unacceptable sentences for the SP task no word of less than 4 letters was ever scrambled; the first letter of the word was never changed; and the position of the scrambled word was evenly distributed over the length of the sentence.

Procedure. The S was instructed to respond yes to acceptable sentences and no to unacceptable sentences, and was given an example of each. The ratio of acceptable to unacceptable sentences was 2:1 in the SP and MN tasks. Each S saw a total of 216 different experimental sentences, plus 36 practice sentences, presented in 7 blocks of 36 trials apiece. In the PR task S saw only the 144 acceptable sentences plus 24 practice sentences.

On each trial S viewed the context for 4 sec; 1 sec. later the sentence appeared and S had 4 sec. in which to respond. There was a 1.5 sec. delay before the next trial began. The entire procedure required 1 hour and 5 minutes for the SP and MN tasks and 1 hour and 15 minutes for the PR task.

Apparatus and Subjects. The typewritten sentences were projected on a wall in a dimly illuminated room. The visual angle subtended by the stimulus was comparable to that in normal reading. Events were controlled and RTs were automatically measured and recorded by a PDP-8 computer.

Subjects were undergraduate and graduate students at the State University of New York at Stony Brook, and were either paid or received credit toward a course requirement. Subjects were screened to make sure that they were native speakers of English.

Results and Discussion

The results are shown on page 2 of the handout. The relative frequency of response errors in the SP and MN conditions were very low, averaging 3.1 percent for false negatives and 14.1percent for false positives. In the PR condition Ss had no trouble generating paraphrase or continuation sentences. In scoring

protocols, a response was considered acceptable if it expressed a complete thought and was obviously related to the stimulus sentence. The average percentage of unacceptable responses per S was about 17.

First I will consider the RT data for the neutral context condition only, which you see in the left-hand figure. Three effects are apparent here: task, sentence type, and an interaction of task with sentence type. An overall analysis of variance(including all context conditions) on RT for correct responses to acceptable sentences showed a non-significant effect of task ($F(2, 27) = 2.15$, $p > .05$), but significant effects of sentence type ($F(2, 54) = 162.43$, $p < .001$) and task by sentence type ($F(4, 54) = 19.98$, $p < .001$). Notice that RTs in the SP task were generally longer than those in the MN and PR tasks. This finding is not necessarily inconsistent with the idea that the MN and PR tasks involve additional processes beyond those which occur in the SP condition. The longer RTs may reflect the greater difficulty of the discrimination required in the SP task or differences in relatively uninteresting processes from the present point of view, such as differences in eye movements between tasks.

The sentence type by task interaction is the effect of greatest theoretical interest. Notice that there was virtually no effect of sentence type in the SP task even though large differences obtained elsewhere. This finding suggests that Ss can and did process words in sentences for spelling errors without performing a deeper semantic analysis.

A second point to notice is that RT for both MN and PR increases with respect to SP in going from redundant to informative to ambiguous sentences. There is a tendency for the rate of increase to be somewhat greater for PR than for MN ($F(1, 18) = 4.17$, $.05 < p < .10$). These findings imply that the three types of sentences - redundant, informative, ambiguous - each require successively more interpretation or integration than the former. We had also

predicted that informative sentences would show a greater increase from the SP to MN task than would redundant sentences. This effect clearly did not come out, suggesting either: (a) that our hypothesis that informative sentences require more processing than redundant sentences in order to synthesize a semantic representation is wrong, or (b) that the MN task for some reason failed to tap into this additional processing.

Up till now we have considered results only for the neutral context condition. In the right-hand figure we've plotted the effectiveness of R and D contexts relative to N contexts. The overall analysis for correct responses to acceptable sentences showed three significant effects involving context. These were: (a) a main effect of context, reflecting the fact that R and D contexts generally facilitated RT, ($F(2, 54) = 22.47$, $p < .001$), (b) a sentence type by context interaction, ($F(4, 108) = 29.48$, $p < .001$) reflecting the fact that effects of context were not uniform over sentence types, and (c) a sentence type by context by task interaction, ($F(8, 108) = 22.15$, $p < .001$) which is the theoretically interesting effect. You can see components of this triple interaction in the top and bottom panels of figure 2. The top panel represents the SP task. Notice that both R and D contexts were less effective for informative than for redundant sentences, and even tended to increase rather than decrease RT for ambiguous sentences. This trend from redundant to informative to ambiguous sentences was significant ($F(2, 18) = 9.75$, $p < .01$).

Another part of the sentence type by context by task interaction appears in the bottom panel of figure 2. It appears that R contexts had the greatest effect for ambiguous sentences in the PR task. We tested this effect by comparing the N-R scores for informative minus ambiguous sentences in MN to the same difference in PR. That comparison did not reach an acceptable level of significance ($F(1, 18) = 1.63$, $p > .05$).

The results for R and D contexts seem to say two things. The decrease in effectiveness that you see in Fig. 2A suggests

that when given a context, Ss tended to process to a "deeper" level then required for the SP task. This apparently had less effect for redundant sentences where further processing is relatively trivial than for ambiguous sentences where the additional processing is not so trivial. The trend that we saw in Fig. 2C tends to confirm the ideas that: (a) ambiguous sentences involve more interpretation in terms of prior non-linguistic knowledge than do informative sentences, (b) that more interpretation occurs in the PR task than in MI, and (c) that R contexts affect the interpretation component.

Conclusion

The present results are consistent with the idea that comprehension involves two of the three component processes mentioned earlier, i.e., retrieval of word meaning constraints and interpretation on the basis of prior non-linguistic knowledge. However, these results provide little evidence for the intermediate component, i.e., synthesis of a semantic representation of a sentence. The only evidence for such a component is the finding that R were more effective in PR than MI, particularly for ambiguous sentences. This result may indicate that the PR task requires a kind of processing not involved in the MI task.

Another way of stating the conclusion is that Ss bring nonlinguistic knowledge to bear in deciding whether a string of words is meaningful. This conclusion is compatible with the views of Bransford and McCarrell (1973) and Olson (1970), but is inconsistent with that of Katz and Postal (1964) who maintain that the semantically interpreted deep structure of a sentence constitutes a full analysis of its cognitive meaning.

On the other hand, one can raise the question of whether bringing nonlinguistic knowledge to bear in the MI task is obligatory. We are concerned that Ss may have processed to a deeper level than required the the MI task.

The presence of R contexts on some trials may have induced S to approach every sentence by trying to infer its theme or referent. In other words, Ss may have been deciding whether sentences were meaningful on the basis of whether they could infer a reasonable theme or referent.

We are currently running a follow-up study which reduces this source of difficulty by using only a neutral context condition. The new study also incorporates a number of other refinements, such as replacing the PR task with a condition in which Ss judge whether each sentence is related to a theme, and changing the MI task so that the unacceptable sentences are entirely grammatical (i.e., so they violate only selection restrictions).

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Footnotes

[1]A paper presented at the Psychonomic Soceity Meetings, Nov. 1-3, 1973, in St. Louis, Missouri.

[2]The assumption of independent serial stages has proven feasible in specialized models of sentence verification (c.f., Chase & Clark, 1972; Trabasso, 1972). However, such models have little to say about sentence encoding, even in the context of a sentence verification task.

Psychonomic Society Convention, November, 1973

Identification of Component Processes in Sentence Comprehension

Theodore J. Doll, Thomas H. Taylor, & Howard Burton

S.U.N.Y. at Stony Brook

Examples of the materials

Acceptable Sentences

Context Type	Sentence Type	Context	Sentence
N	RDT	** ****	Tires are made of rubber.
D	RDT	bird	An eagle has feathery wings.
R	RDT	Thanksgiving	The cranberry is an edible fruit.
N	INF	****** *	The creaky door scared the young children.
D	INF	molten rock	The village was covered with lava.
R	INF	assassination	The popular president died suddenly.
N	AMB	*******	He feared falling through in warm weather.
D	AMB	worry	The bright sparks caused great dismay.
R	AMB	prospecting	Washing left nothing but pebbles.

Unacceptable Sentences

Task	Context Type	Context	Sentence
SP	N	*******	Mercury is liquid at room tapmeertrue.
SP	D	fire	His pacirting was accompanied by smoke.
SP	R	tea party	The hobrar turned reddish brown.
MN	N	* *****	Room is a liquid at mercury temperature.
MN	D	fire	His accompaniment was by practicing smoke.
MN	R	tea party	The reddish brown turned harbor.

FIG. 1. NEUTRAL CONTEXT CONDITION

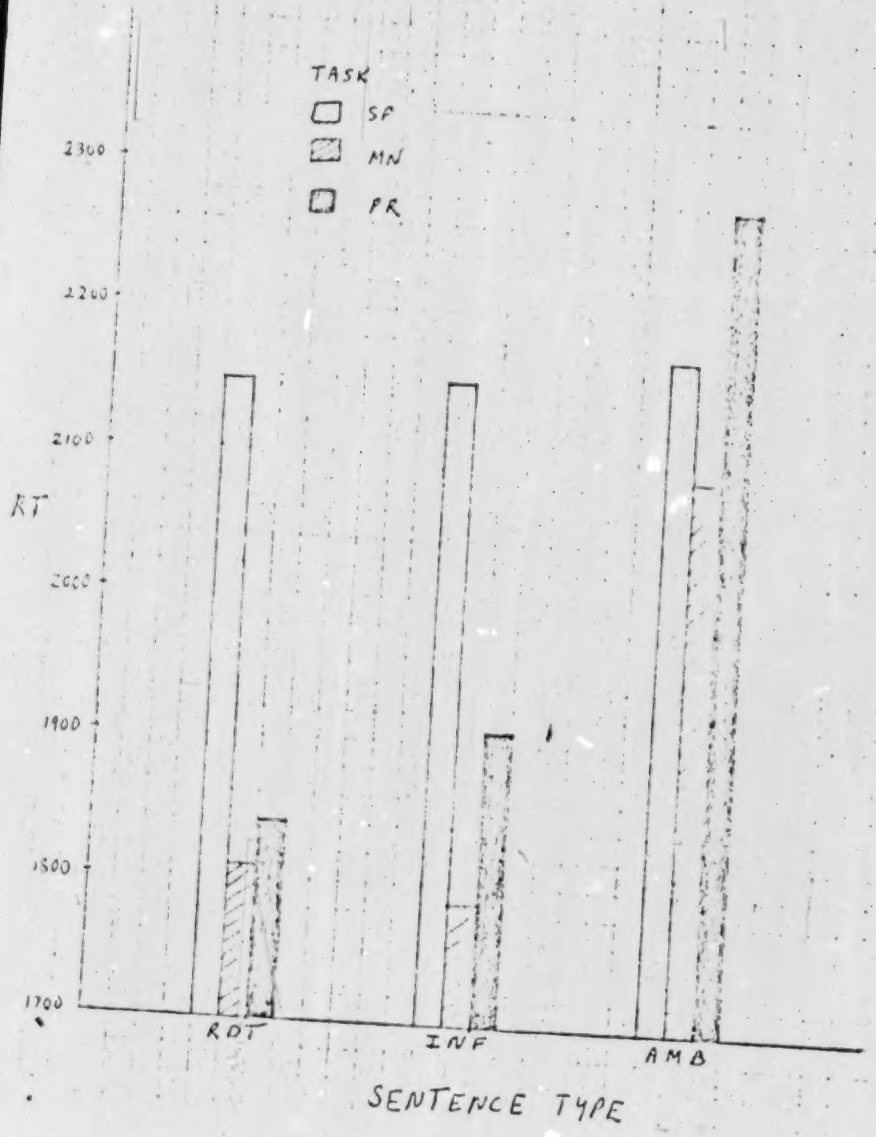
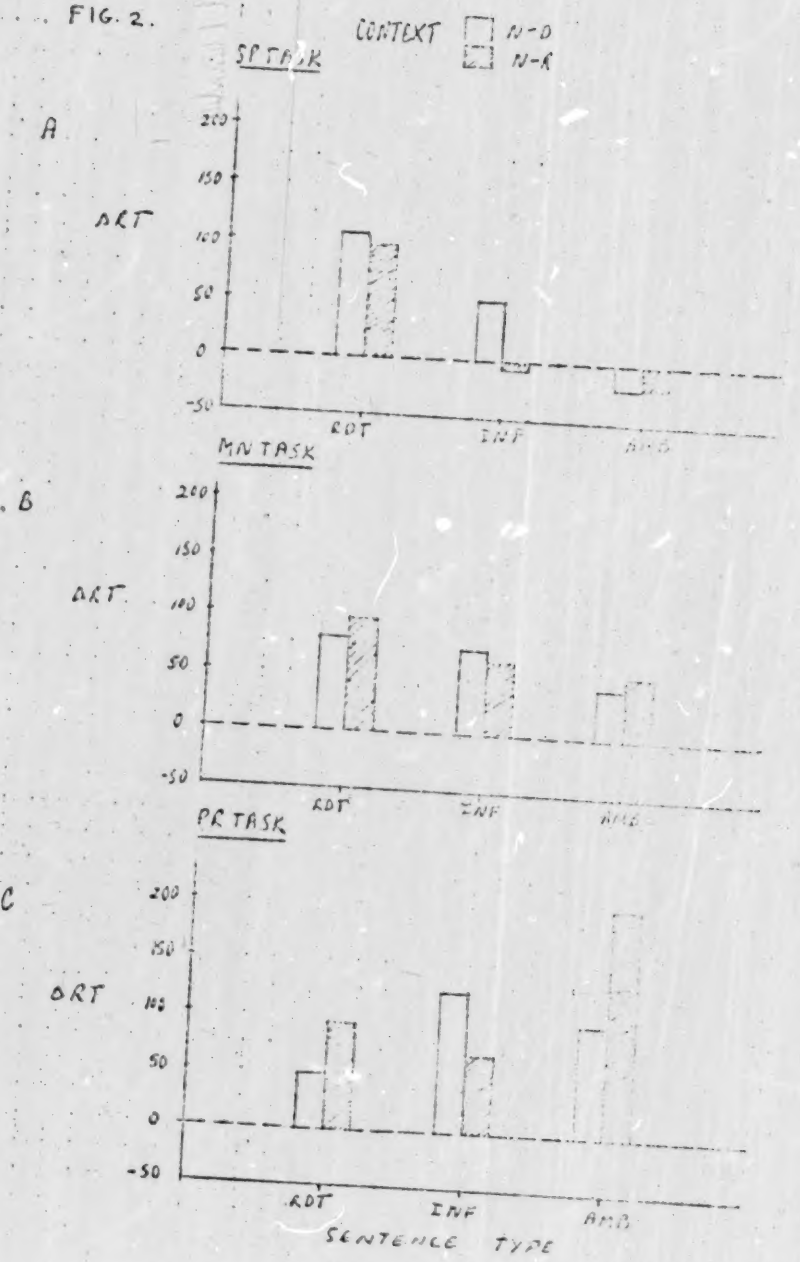


FIG. 2.



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